Characteristics of the Spacecraft Local Environment during NSTAR Ion Propulsion System Operations on Deep Space One

David E. Brinza, Michael D. Henry, Roy Y. Kakuda, Joseph J. Wang, Bruce Tsurutani
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Karl-Heinz Glassmeier, Guenter Musmann, Ingo Richter, Carsten Othmer
Institute for Geophysics and Meteorology
Technical University of Braunschweig
Braunschweig, Germany

Ira Katz
Maxwell Technologies
San Diego, California

ABSTRACT

The Deep Space One (DS1) mission is validating the use of ion propulsion technology for interplanetary spacecraft primary propulsion. The NASA SEP Technology Applications Readiness (NSTAR) Project developed the Ion Propulsion Subsystem (IPS) for DS1. Part of the NSTAR validation effort is understanding the local environment produced during IPS operations and its effects on spacecraft subsystems and science instruments. An integrated, comprehensive set of diagnostics, the NSTAR Diagnostics Package (NDP) was developed and operated on DS1 to characterize the IPS environment. NDP was designed to characterize the contamination environment, charge-exchange xenon (CEX) plasma, plasma and electromagnetic noise and magnetic fields associated with IPS. NDP contamination monitors include two quartz crystal microbalance and optical solar reflector calorimeters mounted in shadowed and direct line-of-sight locations with respect to the NSTAR thruster. The CEX plasma potential and electron temperature are characterized by two Langmuir probes. CEX ion energies are measured with a retarding potential analyzer to determine the internal potential of the ion plume. Electrostatic noise due to fluctuations in the local plasma are measured with a 2-meter tip-to-tip dipole antenna with pre-amplifier. Low-frequency (<100 kHz) electromagnetic noise is monitored with a single-axis miniaturized search coil. The plasma wave antenna and search coil outputs are analyzed via a swept-frequency spectrometer and by direct capture of waveforms. Very-low frequency (DC to 10 Hz) magnetic field measurements are made by a pair of tri-axial flux gate magnetometer sensors with sub-nanoTesla sensitivity. Complementary measurements of IPS environments are made using the Plasma Experiment for Planetary Exploration (PEPE) ion/electron spectrometer developed by Southwest Research Institute and Los Alamos National Laboratory.

During the technology validation phase of the DS1 mission, valuable data were collected from the NDP under a variety of IPS operating conditions. Contamination rates for surfaces with direct line-of-sight to the NSTAR ion engine have been determined and were less than observed for collimated witness specimens in ground test. Temperatures and densities of the CEX plasma were entirely consistent with pre-flight modeling predictions, but differ substantially from characteristics measured in ground test. Plasma noise measurements indicated that hydrazine thruster firings can produce higher amplitude signals than nominal IPS operations. Variations in the IPS plasma noise amplitude did not directly correlate with IPS thrust magnitude, instead the noise level is sensitive to propellant utilization and neutralizer operating conditions. Interesting interactions of the NDP Langmuir probes with internal IPS ground potential, CEX ion fluxes and electrostatic plasma noise have been observed and interpreted. Variation of the DC magnetic fields due to temperature effects on the permanent ring-cusp magnets within the NSTAR thruster have been characterized and are reliably subtracted from the flux-gate magnetometer data to allow monitoring of the space environment. Direct measurement of CEX ions by PEPE at the opposite end of the DS1 spacecraft and the effect of IPS operations on photoelectrons have contributed substantially to the understanding of the spacecraft environment on DS1.